User Guide for Network Rail Variable Usage Charging Model

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1 INTRODUCTION

TTCI(UK) LTD has developed a Microsoft® Excel spreadsheet model for calculating variable usage charges. The model incorporates a revised variable usage charging methodology combining the existing methodology, which addresses track and structures damage from vertical forces, with a new methodology for handling the surface damage from lateral and longitudinal forces. The methodology is described in detail in Reference 1.

The spreadsheet is based on Network Rail's existing variable usage charging spreadsheet but includes, in addition to the additional surface damage calculations, an improved structure that facilitates conversion of the model to a relational database format. It may be used for system-wide or route-specific analyses.

The following sections provide a brief description of the spreadsheet structure, along with directions for use, including procedures for adding vehicles. Summary process flowcharts describing track, structures and surface damage methodologies are included in the appendix.

Throughout this user guide, Excel worksheet and named ranges will be referred to in the following format:

- *Sheet (Name)*
- *Range (Name)*

2 SPREADSHEET STRUCTURE

2.1 General

User interface is principally through three main worksheets where the user enters route and vehicle data, vehicle costs are calculated, and results are presented. There are 11 additional worksheets that provide lookup data and background calculations. These worksheets may occasionally require user input, but should generally remain constant.

The three main working sheets are

- *Sheet (Aggcosts)* ― route expenditures and variable cost percentages for the current year are entered and summary vehicle cost data is presented. A provision is also provided to uplift costs for subsequent years.
- *Sheet (Passenger)* ― individual passenger vehicle annual mileage is entered and individual vehicle cost in pence per mile calculated.
- *Sheet (Freight)* ― individual freight vehicle tonnage and mileage is entered and individual vehicle cost per thousand gross tonne-miles (kGTM) calculated.

The 11 additional worksheets provide:

- Detailed passenger and freight vehicle characteristics
- Commodity data for freight vehicles
- Vehicle curving performance data for surface damage calculations
- Route curvature distribution
- Various parameters and constants used in cost formulae

Where possible, named ranges are used to reference lookup tables. This helps to make worksheet formulae more transparent. More importantly, when a lookup table is expanded, only the range reference address needs to be updated — the formulae that refer to the range may remain unchanged. Named range addresses are identified by a shaded area as indicated in Figure 1. Table A1 in the appendix briefly describes the named ranges used for the lookup tables.

Data Table				

Figure 1. Shaded Area Indicating Named Range Address

Throughout the Excel model, as Figure 2 shows, cells are colour-coded by their use.

	Light blue cells -- data to be entered by user
	Dark Blue cells -- data to be entered by administrator
	Light green cells -- data looked up
	Light yellow cells -- calculated values

Figure 2. Colour Coding

2.2   Principal User Interface Worksheets

2.2.1 Aggregated Costs

Sheet (Aggcosts) is the main cost entry and summary data sheet. Here the user provides route expenditure data and variable cost percentages (see Figure 3)

	% variable	Expenditure (million)	
		Total	Variable
Track (exc RSD)			
Maintenance	32	£428.7	£137.2
Renewals			£0.0
Plain Line	22	£489.1	£107.6
S&C	38	£158.1	£60.1
Total Track (exc RSD)		£1,075.9	£304.9
Surface Damage (RSD)			
Maintenance	32	£42.1	£13.5
Renewals			
Plain Line	22	£41.5	£9.1
S&C	38	£23.3	£8.9
Total Surface Damage		£106.9	£31.5
Structures	10	£371.3	£37.1
Signals	5	£121.6	£6.1

Figure 3. Input Data from Sheet *(Aggcosts)*

A summary of vehicle miles, gross tonne miles, vehicle miles, equivalent gross tonne miles, equivalent vehicle miles along with cost allocated to track, structures, and surface damage is provided. This sheet also displays the key multipliers *Cost per thousand EGTM* and *Cost per EVM* that are used to calculate per vehicle costs. A provision for uplifting costs for subsequent years is also provided. Separate uplifts are entered for freight and passenger.

2.2.2 Passenger Vehicles

Sheet (Passenger) accepts individual passenger vehicle mileage data from the user, looks up vehicle characteristics from various sources, and calculates individual passenger vehicle cost in conjunction with *Sheet (Aggcosts).*

The following values must be entered by the user in the first two columns:

- Vehicle Class
- Annual Mileage

The following values are then looked up from *Range (Pax_Veh_Data)* and *Range (Pax_Curving_Class)*, which is described in Subsection 2.3.1.

- Group
- Type
- Comments
- Tare Weight with Passengers
- Maximum Speed
- Operating Speed
- Number of Axles
- Unsprung Mass
- Curving Class

Cost in pence/vehicle-mile is calculated for each vehicle. If uplift percentages have been entered for later years, uplifted vehicle costs will also be presented.

2.2.3 Freight Vehicles

Sheet (Freight) accepts individual freight vehicle mileage and tonnage data from the user, looks up vehicle characteristics from various sources, and calculates individual freight vehicle cost in conjunction with *Sheet (Aggcosts)*.

The user provides the following values for each vehicle:

- Vehicle Class
- Laden or Empty
- Annual Tonnage
- Annual Mileage
- Commodity Type

The following values are looked up from *Range (Frgt_Veh_Data)* and *Range (Frgt_Curve_Class)*:

- Locomotive or Wagon
- Comments
- Group
- Vehicle Weight
- Operating Speed ─ based on commodity type
- Number of Axles

- Unsprung Mass
- Curving class

Cost in pounds/kGTM is calculated for each vehicle. If uplift percentages have been entered for later years, uplifted vehicle costs will also be presented.

2.3 Vehicle Data — General

2.3.1 Passenger and Freight Vehicle Characteristics

Sheet (Pax Veh Data) and *Sheet (Frgt Veh Data)* contain lookup tables with detailed passenger and freight vehicle characteristics to be used in cost calculations. The lookup tables are referenced by the named ranges *Range* (*Pax_Veh_Data)* and *Range* (*Frgt_Veh_Data).*

The various lookup functions will search the Class column for an exact match and return the appropriate information. If an exact match is not found, "Missing Data" will appear in the lookup cell.

2.3.2 Commodity Data

Network Rail reports freight vehicle usage for 21 commodity types, while only 6 are used in the ORR usage charging scheme. For this reason, two lookup tables designated by named ranges *Range* (*Commodity_Data)* and *Range (Commodity_Data_NR)* are used to relate the 21 Network Rail commodities to the 6 ORR commodities.

Range (Commodity_Data) contains the six ORR commodities, along with the following data for each:

- Average Speed (where applicable)
- Default Wagon Load (not populated at this time)
- Speed Loaded
- Speed Empty
- Average Speed for Locomotive
- Spillage Factor

Range (Commodity_Data_NR) references the 21 Network Rail commodities to the ORR commodities and provides the appropriate data to the cost calculation sheets.

2.3.3 Parameters

Sheet (Parameters) contains various coefficients used to calculate vertical force charges. These values relate to:

- Conversion of Maximum Speed to Commercial Speed
- Axle Load Factor
- Speed Factor
- Unsprung Mass Factor
- Structures Factor

In addition, there is a lookup table contained in the named range *Range (RSTOCK)* that contains rolling stock related factors. These include:

- Vehicle Group
- Rolling Stock Factor
- Dirt Factor
- 2-Axle/4-Axle Factor

2.4   Vehicle Surface Damage

2.4.1 Curving Class

Each vehicle is assigned a Curving Class, which defines its surface damage propensity.

Lookup tables are provided, *Range (Pax_Curve_Class) and Range (Frgt_Curve_Class)*, which relate passenger and freight Vehicle Class to Curving Class.

For freight vehicles other than locomotives, the suspension band is automatically read from *Range (Frgt_Veh_data)* and entered in *Range (Frgt_Curv_Class)*. The suspension band is then related to surface damage bogie type via *Range (SusBand_BogieType)*. Finally the bogie type is converted to Curving Class via formulae within *Range (Frgt_Curv_Class)*.

Locomotives are automatically identified within *Range (Frgt_Curve_Class)*, but the Curving Class for locomotives must be entered manually.

Range (SusBand_BogieType) currently holds six suspension bands with provision for a seventh.

2.4.2 Surface Damage Calculation

Sheet (Axle Surf Damage) calculates a Net Surface Damage Factor for each vehicle Curving Class on each curvature considered. T-gamma values obtained from modelling are manually entered in the dark-blue shaded cells.

Sheet (Vehicle Surf Damage) then combines the net Cost Factor for the route curve distribution to determine a cost per mile for each Curving Class. The cost per mile data is contained in *Range (Vh_Dmg)* and supplied to the cost calculation sheets.

Sheet (Curve) contains the curvature distribution in kilometres. This distribution is used to calculate Vehicle Surface damage. It may be changed to reflect the curve distribution of the specific route in question.

2.4.3 Constants

Sheet (Constants) contains six constant values used for calculating Surface Damage:

- Grinding Cost
- Renewal Cost
- Depth Ground
- Side Wear Limit
- Crack Damage Rate
- Wear Damage Rate

3 INSTRUCTIONS FOR USE

3.1 General

The following procedures should be used assuming that the model currently contains data for all vehicles to be included. See Subsection 3.2 for procedures for adding vehicles.

- Cost input
  - Enter route or system maintenance and renewal costs in light-blue cells on *Sheet (Aggcosts).*
  - Enter variable usage percentages in light-blue cells on *Sheet (Aggcosts)*
- Passenger traffic input
  - Enter passenger Vehicle Class along with annual vehicle miles (in thousands) in the first two columns of *Sheet (Passenger).*
- Freight traffic input

- Enter freight Vehicle Class along with annual vehicle miles (in thousands) and tonnage (in thousand gross tonnes) in the first three columns of *Sheet (Freight)*.

- Enter whether the vehicle is laden or empty in the fourth column. Enter "Y" for laden or "N" for empty. Enter "N" if the vehicle is a locomotive. Either upper or lower case letters are allowed. By definition, locomotives are entered as "N".

- Enter the commodity in the fifth column. Commodity names must exactly match the list of Network Rail commodities listed in the appendix. If an unrecognised commodity is entered, "Missing Data" will appear in the Operating Speed column.

- Vehicle data input

  - Check for missing data on *Sheet (Passenger)* and *Sheet (Freight)*.

    - Reference to missing or assumed data may be recorded in the Comments column. The entry "Missing Data" will appear if the vehicle is not included in the lookup tables. See Subsection 3.2.1 if a vehicle needs to be added.

    - The entry 'Missing Data" will appear in the Curving Class column if a Curving Class is not assigned to the vehicle. See Subsection 3.2.1 if a vehicle with an existing Curving Class is to be added or Subsection 3.2.2 if a vehicle and a new Curving Class are to be added.

- Surface damage input

  - Enter appropriate system or route curvature distribution (in kilometres) on *Sheet (Curves)*. The Base Case spreadsheet provided to Network Rail has the curvature distribution for the entire system.

- Model output

  - Read passenger vehicle costs for the current year in pence per mile from *Sheet (Passenger)*.

  - Read freight vehicle costs for the current year in £/kGTM from *Sheet (Freight)*.

  - If uplift values for later years are required, enter uplift percentage in the cells provided on *Sheet (Aggcosts)*. Columns with uplifted costs will be appended to the appropriate sheet for each year for which a percentage is entered.

3.2   Addition of Vehicles

If a new vehicle is to be added to the model, the following changes must be made.

3.2.1 Enter New Vehicle Characteristics

- Insert a row and add the Vehicle Class with annual mileage/tonnage, etc. to either *Sheet (Passenger)* or *Sheet (Freight)*. Copy all formulae from the row above. Note that formulae exist in the Price Uplift columns even though they may be blank. Ensure that totals at the bottom of the page include the new row.

- Add a row to either *Range (Pax_Veh_Data)* or *Range (Frgt_Veh_Data)*, as appropriate. Ensure that range address reference includes the new row. Enter the following data, as appropriate:

    – Vehicle Class

    – Group (passenger only)

    – Locomotive "Y" or "N" (freight only)

    – Type (passenger only)

    – Tare with Passengers (tonnes)

    – Tare (freight wagons)

    – Maximum Speed (passenger only)

    – Operating Weight (freight only)

    – Operating Speed

      ▪ For passenger vehicles, vehicle operating speed is generally calculated from maximum speed based on the formula Operating speed = A*Maximum speed^B, with the parameters A and B provided as described in Subsection 2.3.3. However, in some cases, a different value has been provided. If this is the case, the value should be entered manually in *Range (Pax_Veh_Data)*, with the affected cell colour coded light blue, and an appropriate comment entered.

    – Number of Axles

    – Unsprung Mass

    – Suspension Band (freight only)

    – Comments as Appropriate

3.2.2 Add a New Curving Class (if required)

If the vehicle to be added will use a new Curving Class the following procedures apply:

- Determine vehicle T-Gamma values for each axle at the route curvature ranges presented in the appendix.
- On *Sheet (Axle Surf Damage):*
  - A row will be required for each axle of the new vehicle with an additional line for totals. Enter the name of the new Curving Class in Column A.
  - Add appropriate labels (Axle number or Total) in Column B.
  - Copy formats and formulae from Columns S-CD into lines for each axle. These formulae are identical from row to row.
  - Add Net Damage totals in Columns BO-CD.
  - Enter T-Gamma values for each axle in Columns C-R. Shade these cells light blue.
- On *Sheet (Vehicle Surf Damage)*:
  - Add a line to *Range (Vh_Dmg)*. Ensure that range reference address is updated. Enter the name of the new Curving Class in Column A
  - Copy formulae and formats from Columns B-S. Modify copied formulae to reference appropriate row in *Sheet (Axle Surf Damage)*
- Freight Vehicles Only:
  - Modify *Range (SusBand_BogieType)* to include additional Suspension Band referring to new Curving Class. Assure that range reference address includes new data.

3.2.3 Update Curving Class Tables

Whether or not a new Curving Class has been added, make the following updates:

- For a passenger vehicle, add a row to *Range (Pax_Curve_Class)* and enter the Vehicle Class and Curve Class. Ensure that range address reference includes the new data.
- For a freight vehicle, add a row to *Range (Frgt_Curve_Class).* Enter the Vehicle Class. Copy the formulae and formatting from *Columns B-G* to the new row.

REFERENCE

1. Tunna, John. 23 April 2007. "A Revised Methodology for Variable Usage Charging," UK NR Report No. 07-003, TTCI(UK) Ltd, London.

APPENDIX
Range Names
Network Rail Commodity Types
System Curvature Distribution
Variable Usage Charging Methodology Flowcharts

A1 Range names

Table A1 briefly describes the named ranges used for lookup tables.

Table A1. Description and Location of Named Ranges used for Lookup Tables

Range Name	Description	Location
Range (Commodity_Data)	ORR commodities with speeds and loads	*Sheet (Commodity Data)*
Range (Commodity_Data_NR)	Cross reference ORR to Network Rail commodities	*Sheet (Commodity Data)*
Range (Frgt_Curve_Class)	Curving Class for each freight vehicle based on bogie type	*Sheet (Freight Curve Class)*
Range (Frgt_Veh_Data)	Freight vehicle characteristics	*Sheet (Frgt Veh Data)*
Range (Pax_Curving_Class)	Curving Class for each passenger vehicle	*Sheet (Pax_Curve_Class)*
Range (Pax_Veh_Data)	Passenger vehicle characteristics	*Sheet (Pax Veh Data)*
Range (RSTOCK)	Rolling stock factors for vertical damage calculations	*Sheet (Parameters)*
Range (SusBand_BogieType)	Cross reference freight vehicle Suspension Band to bogie type	*Sheet (Frgt Curve Class)*
Range (Vh_Dmg)	Vehicle damage per mile for surface damage calculations	*Sheet (Vehicle Surf Damage)*

A2   Network Rail Commodity Types

Table A2 presents Network Rail commodity names, which must be entered exactly for each freight vehicle considered.

Table A2. Network Rail Commodities

Commodity
Domestic Automotive
Domestic Intermodal
European Automotive
European Intermodal
Coal ESI
Iron Ore
Mail and Premium Logistics
Royal Mail
Chemicals
Coal Other
Construction Materials
Domestic Waste
Engineering Haulage
Enterprise
European Conventional
General Merchandise
Industrial Minerals
Non Reportable
Other
Petroleum
Steel

A3   System Curvature Distribution

Table A3 presents the system curvature distribution used in the model.

Table A3. Network Rail System Curvature Distribution

Radius (m)	Track kilometres
0 – 300	83
301-500	334
501-700	778
701-900	1879
901-1100	1193
1101-1300	1193
1301-1600	1193
1601-2000	1885
2001-2400	1718
2401-2800	1718
2801-3500	1718
3501-5000	4294
5001-7000	0
7001-9000	0
9000-11000	0
11000 +	11110
Totals	29096

A4   variable usage charging methodology Flowcharts
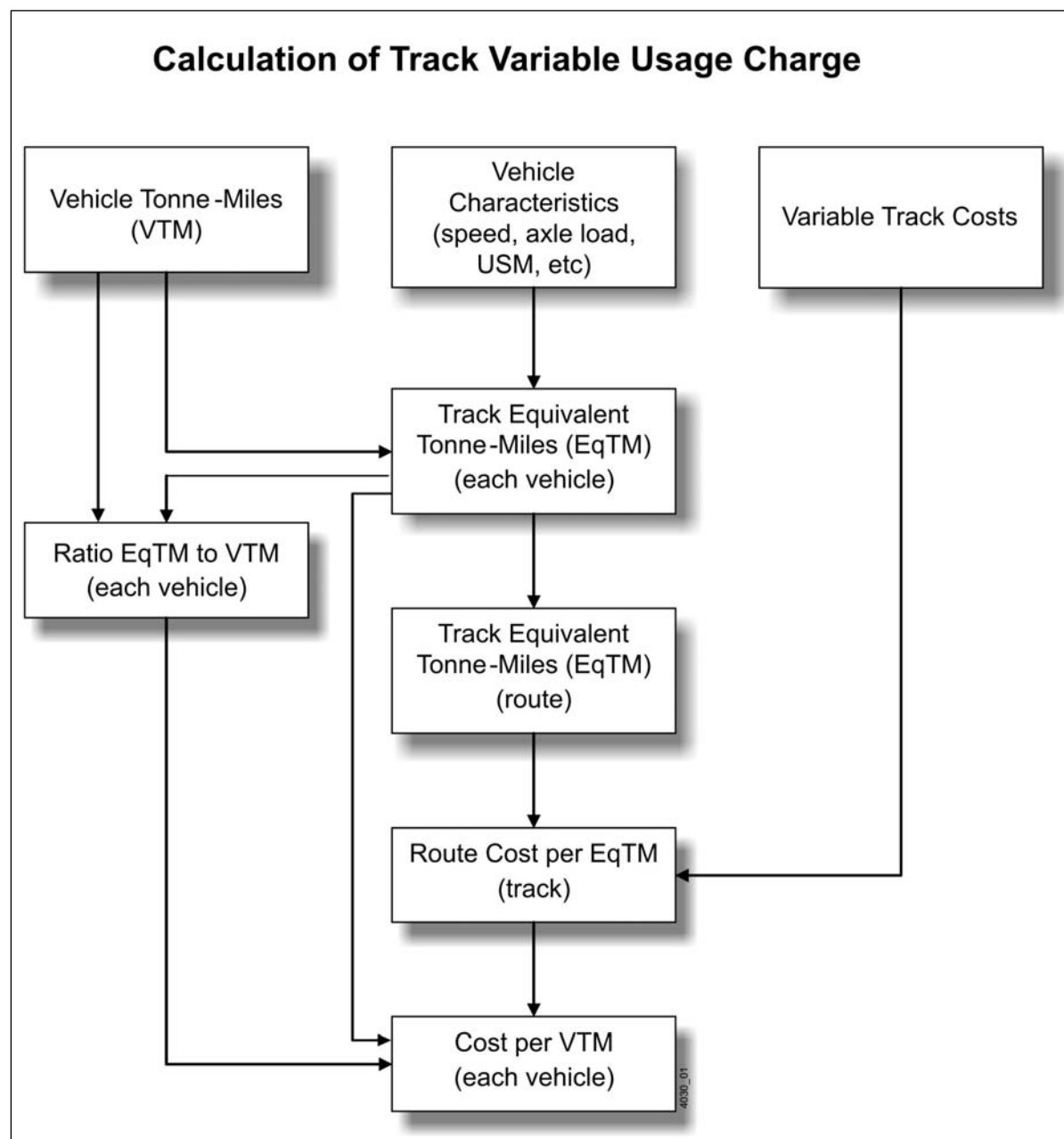
Figure A1. Track Variable Usage Charge Methodology Flowchart

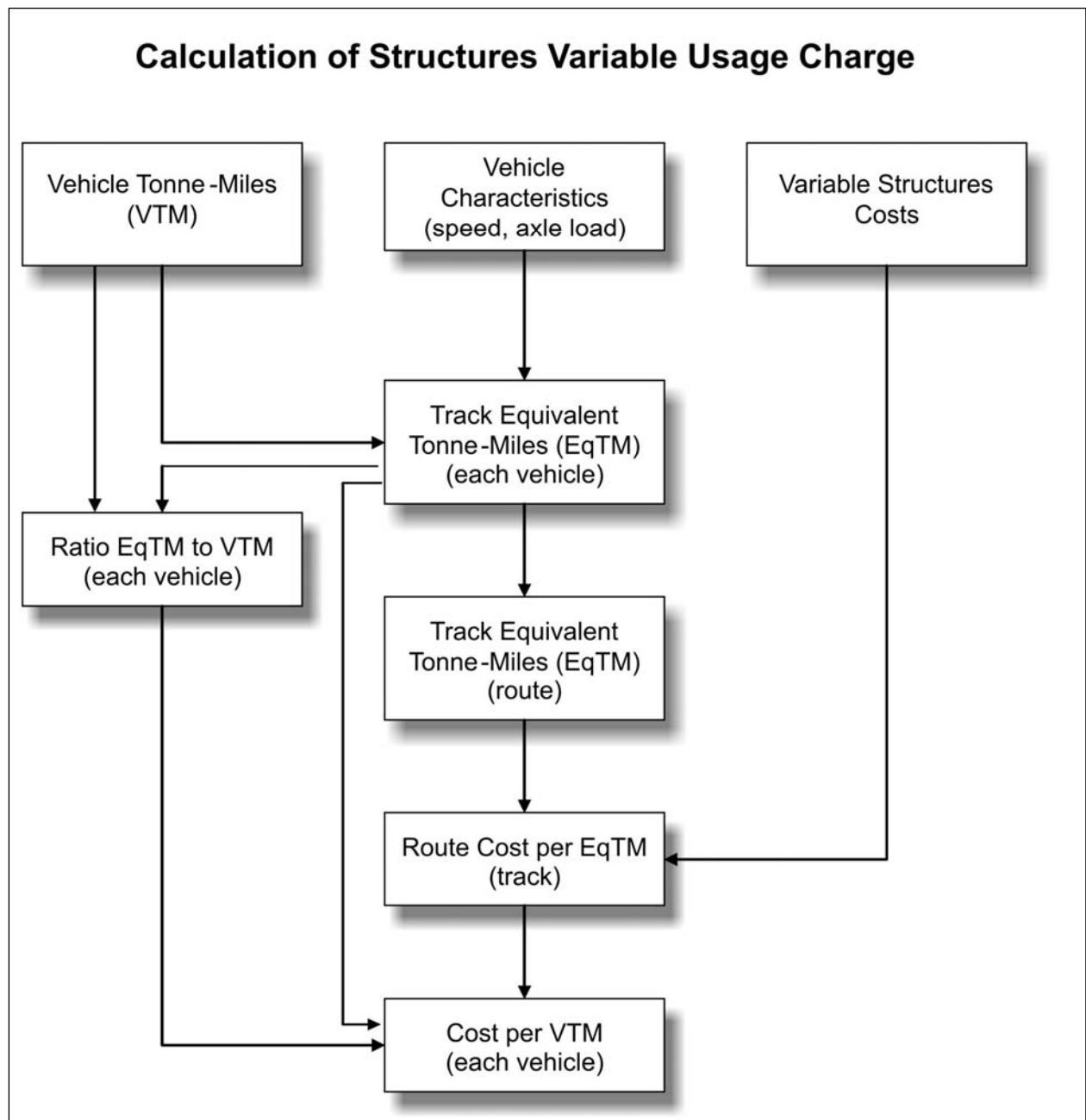## Calculation of Structures Variable Usage Charge

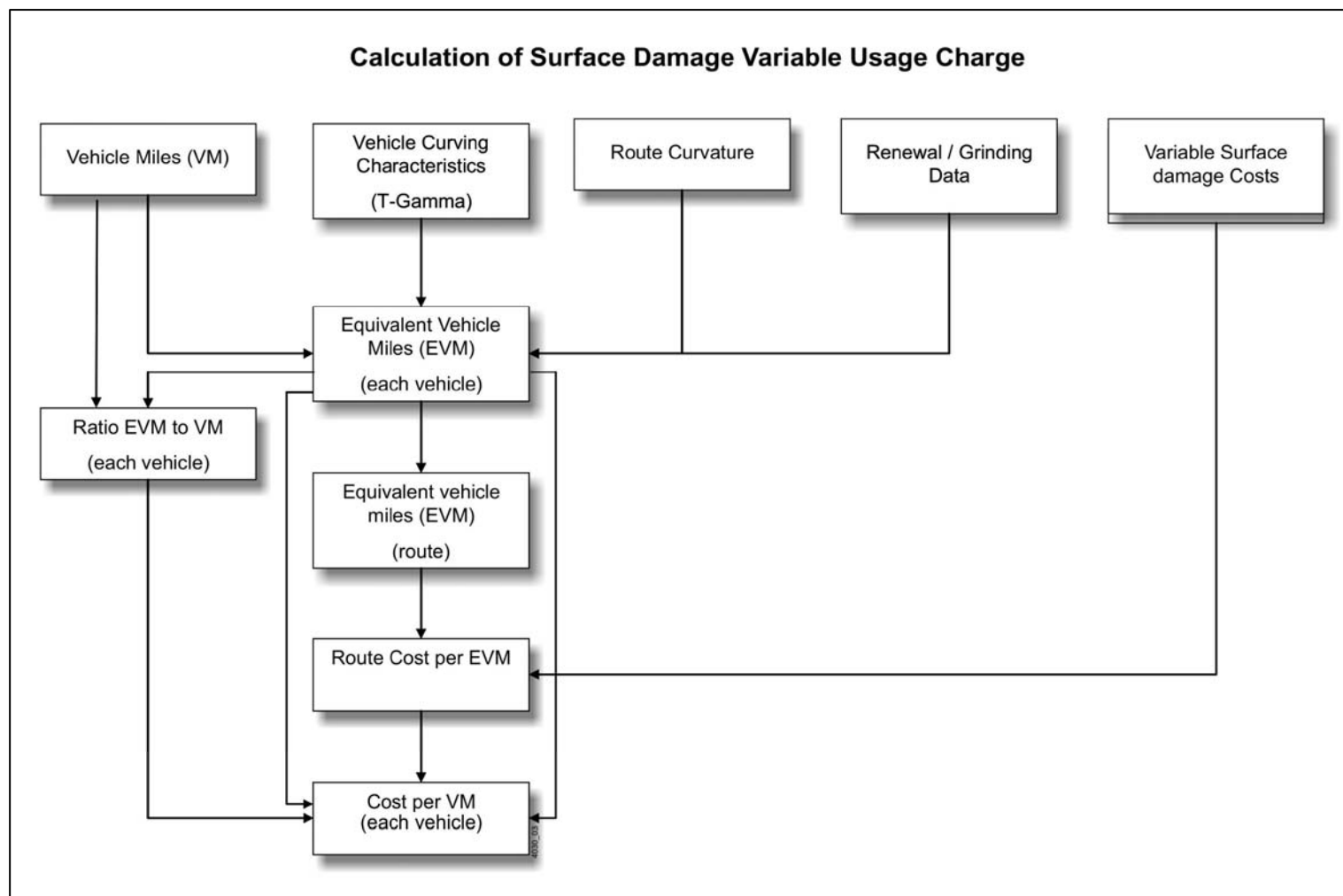**Figure A2. Structures Variable Usage Charge Methodology Flowchart**

Figure A3. Surface Damage Variable Usage Charge Methodology Flowchart